front of or behind the thrower; in each of these cases success has been attained. An explanation is also afforded of the returning of a boomerang without "twist," made by Mr. O. Eckenstein, and of the wonderfully long, straight trajectories of some of the native non-returning implements.

"Condensation of Water Vapour in the presence of Dust-free Air and other Gases." By C. T. R. WILSON, B.Sc. (Vict.), M.A. (Cantab.), of Sidney Sussex College, Clerk-Maxwell Student in the University of Cambridge. Communicated by Professor J. J. THOMSON, F.R.S. Received March 15, Read April 8, 1897.

(Abstract.)

In a note read before the Cambridge Philosophical Society (May 13, 1895) I stated, as the result of some preliminary experiments, that when air, originally saturated with aqueous vapour, undergoes sudden expansion exceeding a certain critical amount, condensation takes place in the form of drops throughout the moist air, even in the absence of all foreign nuclei.

The present paper contains an account of the measurements which were afterwards made of this critical expansion in air and other gases, as well as of further phenomena which have since been observed in connection with the condensation of aqueous vapour from the supersaturated state.

Two different forms of expansion apparatus have been used. Both were designed to enable a given sample of the saturated gas to be suddenly expanded as often as might be desired without any risk of foreign nuclei entering. All such nuclei originally present were removed by repeatedly forming a cloud by expansion and allowing it to settle, till expansions of moderate amount ceased to cause any visible condensation. In both forms of apparatus a definite expansion of any desired amount could be produced. They were designed to give an exceedingly rapid expansion, the rate at which the volume was increasing being greatest, too, just before the expansion was completed, when the temperature was lowest and the influx of heat from the walls most rapid; so that, as indeed appears from the constancy of the results obtained, the theoretical lowering of temperature must have been very nearly reached.

The two machines, in spite of the fact that the volume of the air in the first was twenty times as great as that contained in the second, gave identical results. The larger machine was only used in the experiments on air.

If air, initially saturated and free from all foreign nuclei, be suddenly allowed to expand, a rain-like condensation results if the ratio of the final to the initial volume, v_2/v_1, exceeds 1·252; no condensation taking place except on the walls of the vessel with smaller expansions.

When v_2/v_1 exceeds 1·252 the condensation continues to be rain-like, showing over quite a wide range no visible increase in the number of the drops with increasing expansion, till a second quite definite limit is reached when v_2/v_1 lies between 1·37 and 1·38. With expansions greater than this the condensation is cloud-like, the number of the drops which are formed increasing at an enormously rapid rate with increasing expansion. If v_2/v_1 be made successively greater and greater, a very definite series of colour phenomena is observed as this ratio is increased from 1·38 to 1·44, indicating a very rapid diminution in the size, and corresponding increase in the number of the cloud particles with increasing supersaturation. Only the smaller apparatus was used in the experiments on the cloud-like condensation, the time taken for the expansion to be completed being much shorter than in the other.

Experiments were made upon the condensation phenomena in the presence of oxygen, hydrogen, nitrogen, chlorine and carbonic acid.

Of these, all except hydrogen were alike in showing the two forms of condensation, each requiring a definite degree of supersaturation to produce it.

Chlorine is too far removed from the condition of a perfect gas to enable the lowering of temperature and resulting supersaturation to be calculated. This can be done, however, in the case of the other gases.

By the supersaturation is here meant the ratio of the actual density of the vapour when the expansion has just been completed, and the minimum temperature has therefore been reached, to the density of the vapour in equilibrium over a flat surface of water at that temperature.

We may summarise the results obtained with the various gases, including air, as follows:—

In order that rain-like condensation may result in the presence of any of these gases, except hydrogen, the expansion must be sufficient to cause the supersaturation to exceed a certain value, amounting, when the final temperature is $-6°$ C., to between 4·2 and 4·4, and diminishing with rising temperature.

In order that cloud-like condensation may take place in the presence of any of these gases, including hydrogen, the expansion must be sufficient to cause the supersaturation to exceed a certain value, amounting, when the final temperature is about $-16°$ C., to 7·9.

When the supersaturation reached lies between these limits rain-

like condensation results in all the gases, except hydrogen, in which scarcely any trace of condensation is seen when the supersaturation is even slightly below 7·9.

A statement of the effect of the Röntgen rays upon condensation in the presence of air was given in a note read before the Royal Society, on March 3, 1896. The rays have the effect of greatly increasing the number of the drops, the minimum expansion required to cause condensation being unaltered.

Experiments have been made upon the effect of these rays when hydrogen is substituted for air. Their effect on the moist hydrogen is to introduce nuclei, which only require the supersaturation to reach the same limit as is required for rain-like condensation in air and the other gases, in order that condensation may take place upon them. In all these experiments the X-rays had to pass through glass to reach the gas, and must have been thereby very much reduced in intensity, yet their effect in the case of hydrogen was quite noticeable when the bulb producing them was 120 cm. from the expansion apparatus.

The nuclei which bring about the rain-like condensation are equivalent, in their power of helping condensation, to water drops of $8{\cdot}6 \times 10^{-8}$ cm. in radius, that is, water drops of this size would just be able to grow in vapour supersaturated to the extent actually required to bring about condensation. This number is calculated on the assumption that Boyle's law holds for the supersaturated vapour, and that the surface tension retains its ordinary value even in such small drops. It must, therefore, only be considered as a rough approximation.

On the same assumptions, the nuclei which are able to act as centres of condensation when the supersaturation is sufficient to cause the cloud-like condensation, are equivalent to drops of $6{\cdot}4 \times 10^{-8}$ cm., or less, in radius. They are present, as we have seen, in all the gases tried, when saturated with aqueous vapour, and are exceedingly numerous. It is probable, therefore, that they are actually small water particles, such as one would expect to come into existence momentarily through encounters of the molecules.

The nuclei which bring about the rain-like condensation are always few in number, and they appear to be entirely absent in hydrogen; their number, therefore, depends on the nature of the gas. They are probably, therefore, of a different nature from those which come into play when the supersaturation is great enough to cause the cloud-like condensation.